

QUANTITATIVE COMPARISON OF NEURAL NETWORK AND CONVENTIONAL CLASSIFIERS FOR HYPERSPECTRAL IMAGERY

Erzsébet Merényi¹, James V. Taranik², Tim Minor², and William H. Farrand³

¹Planetary Image Research Laboratory,
University of Arizona, LPL, Tucson, AZ 85721

²Desert Research Institute,
7010 Dandini Blvd, Reno, Nevada 89512

³Analytical Imaging & Geophysics, LLC
540 W. Arrowhead St., Louisville, CO 80027

The Problem

High spatial and spectral resolution measurements made by advanced remote sensors such as *e.g.*, NASA's AVIRIS or the Naval Research Laboratory HYDICE instruments can provide high quality data for analyzing the complex variability of landscape surface cover in different global environments. However, the application of traditional multispectral data analysis tools to hyperspectral data has not yielded satisfactory results because of mathematical and practical limitations. For example, the Maximum Likelihood classifier commonly used for multispectral data consisting of less than 10 bands, requires as many training samples per class as the number of sensor bands plus one. Hyperspectral sensors have hundreds of bands for measurement of landscape cover and therefore hundreds of discrete spectral classes are possible, thus complicating the collection of field samples. The extremely large amount of data that a spectral image represents today also poses problems with regard to processing time.

Combined analysis of hyperspectral data with digital topographic or other geophysical data is usually a complex process, not suitable for traditional methods. Covariance-based methods often fail to detect subtle, but compositionally important, spectral differences. Using feature extraction, to limit the analysis of hyperspectral data to only those bands having "significant" spectral variability, often results in the loss of subtle, but important, landscape information.

Motivation for Systematic ANN Studies

The use of Artificial Neural Networks (ANNs) is motivated by their power in pattern recognition/classification due to the ultimately fine distribution and non-linearity of the process. The textbook of *e.g.*, Pao (1989) gives a good background on the numerous ANN architectures developed for various types of tasks. As a successful implementation of the

parallel computational technique they also hold the promise to provide adequate speed for hundreds of megabytes of data, especially when supported by specialized hardware, which may open the possibility for on-board data reduction in the future.

However, one must have confidence in the quality of the classification before taking real advantage of the speed that Artificial Neural Networks can offer. Artificial Neural Networks have been shown to be well suited for pattern recognition and classification for complicated, noisy patterns. During the past ten years several works demonstrated their power for remote sensing spectral data of Earth and other planetary surfaces (*e.g.*, Benediktsson *et al.* 1990a; Hepner *et al.* 1990; Howell *et al.* 1994; Merényi *et al.* 1993, 1994, 1995a, 1995b, 1995c, 1996; Wang and Civco, 1995). For example, with an ANN researchers have detected compositionally meaningful spectral classes of asteroids that were missed by Principal Component Analysis from the same 60-channel data (Howell *et al.* 1994). Various workers have reported good classification results using ANNs on lower spectral resolution terrestrial images or laboratory data (*e.g.*, Ninomiya and Sato, 1990; Hepner *et al.* 1990, Merényi *et al.* 1994).

A limited number of valuable previous studies tested ANN performance against conventional methods classifying modest amounts of low-resolution data (Huang and Lippman, 1987), or medium resolution synthetic data into 3–4 classes (Benediktsson *et al.* 1990b). The latter favored the Maximum Likelihood classifier by virtue of Gaussian data construction. Benediktsson *et al.* (1990b), Yuan *et al.* (1995) and Merényi *et al.* (1996) are examples of studies for using ANNs to classify fused disparate data. Few (Howell *et al.* 1994, Merényi *et al.* 1993, 1995a, 1995b) have attempted ANN classification of hyperspectral data into a larger number of classes even though that is where the shortcomings of classical methods become debilitating.

Systematic evaluation of ANN classification performance, however, has not yet been conducted on real, hyperspectral data and on the scale of real applications (many classes, large images). This is critical for the confident use of ANNs in large scale integrated, (semi-) automated, on-board or commercial applications. The target of our study is to conduct such a systematic investigation on real data.

This Study and Preliminary Results

This work will present a comparison among ANN classifiers and several traditionally used sequential classification methods such as Maximum Likelihood, Minimum Distance, Mahalanobis Distance, using real hyperspectral data. In particular, a Kohonen type (Kohonen, 1989) Self-Organizing ANN architecture is tested. This neural network paradigm (implementation by NeuralWare, 1991) was selected over the most frequently used backpropagation network for the relative ease in training, and for its capability to make good predictions based on a small amount of training samples. A subset of a 1994 224-channel AVIRIS image is classified into more than a dozen classes after conversion to reflectances with atmospheric correction. The study area is the Lunar Crater Volcanic Field site in Nevada, with a great variety of cover units.

Classifications are performed for several spectral subsampling levels including full spectral resolution. Based on field knowledge and geologic maps, we conclude that the ANN produces comparable or better results than the classical methods in terms of map accuracy. The difference in quality between the performance of classical techniques and ANN classifiers appears to increase in favor of the ANNs with increasing number of channels. We will present spectra for all cover types to demonstrate the subtle discriminating features that the ANN makes use of to distinguish among certain geologically different species. Besides classification accuracy, an additional criterion of performance is the prediction capability based on a very small amount (less than 1%) of the data for training. This aspect is very important in remote sensing image analysis, as the collection of field samples can be costly or in some cases it may be impossible to collect the necessary number of samples for a traditional classifier.

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